On the Specific Inductive Capacity of a Sample of Highly Purified Selenion.

By O. U. Vonwiller, B.Sc., Demonstrator in Physics, and W. H. Mason, B.Sc., Deas-Thomson Scholar in Physics in the University of Sydney.

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General Results of the Measurements.

For the purpose of the electrical measurements, the selenion, purified as described in R. Threlfall's paper, was cast into the form of a circular plate about 15 cm. in diameter and 1 cm. thick. To make the casting, the selenion was heated until thoroughly liquid, which occurred at a temperature between 200° and 230° C., then poured into an open zinc mould previously warmed, and allowed to cool at the air temperature. Under the circumstances the selenion assumed the vitreous form,* the fracture being conchoidal and the specific gravity 4·29 at 13°·8 C. When hard, the end surfaces of the plate were carefully ground flat and parallel to each other, the grinding being done with carborundum powder. After the completion of each set of measurements the plate was broken into small pieces to ascertain if the material was homogeneous throughout; on no occasion were any air bubbles found which could in any way affect the accuracy of the measurements.

Determinations of the specific inductive capacity of the selenion forming the plate so prepared were made by the absolute electrometer method, with alternating electric forces having a frequency of about 50 per second; and by a method using electric oscillations with a frequency of 24,000,000 per second. Table I gives the results obtained, the measurements being made with the selenion in the dark.

The investigation shows that to the order of the accuracy of the measurements for the sample of selenion tested, the specific inductive capacity is the same under alternating electrical forces having a frequency of 24,000,000 per second, as it is under forces whose frequency is only 50 per second.

This result for the sample of selenion is similar to that found for the specimen of glass examined by the same methods as those described in this paper by Pollock and Vonwiller.†

* Saunders, 'Journ. Phys. Chem.,' vol. 4, 1900.

† 'Phil. Mag.,' June, 1902.

Table I.—Values of Specific Inductive Capacity.

By electrometer method.		By electrical oscillation method.	
Temp. ° C.	K.	Temp. ° C.	K.
12·5	6·20	23·0	6·09
12·5	6·07	24·1	6·16
19·3	6·09	23·7	6·16
19·8	6·17	—	—
Means ... 16·0	6·13	23·6	6·14

For the plate of selenion used in the final determination of the specific inductive capacity by the electrometer method, the specific resistance with the selenion in the dark was found to be $2·2 \times 10^{16}$ ohms at 20° C. and $6·5 \times 10^{15}$ ohms at 25° C.; these values are to be considered provisional only, more exact determinations extending over a wider range of temperature are now in progress. The specific resistance decreased considerably when the selenion was exposed to light. The comparatively high conductivity imparted to the plate by the very thin reddish film which forms on surfaces of vitreous selenion, though only exposed to air, gave considerable trouble until its cause was discovered. For all measurements it was found necessary to first remove this film by the careful use of glass paper.

The specific gravity of the material was found by weighing, in air and in water, a whole plate and a fragment after the plate was broken up; the results are identical, giving 4·29 as the value of the specific gravity at 13°·8 and 16°·2 C.

In the report of the Melbourne Meeting of the Australasian Association for the Advancement of Science (1900), Madsen published values of the specific inductive capacity of selenion obtained from measurements with the same sample of selenion as that used in the present determination, but with a different form of absolute electrometer. The mean value given is 5·74; we are, however, satisfied that some source of constant error remained undetected in the measurements, and that the values given are considerably too low.

V. Pirani* measured the specific inductive capacity of commercial selenion and obtained values between 7·4 and 7·58. Sufficient data are not given to enable us to estimate the degree of accuracy attained in this measurement.

* Inaugural Dissertation, Berlin, 1903.

Measurement of the Specific Inductive Capacity by the Absolute Electrometer Method.

The apparatus used was that employed by Pollock and Vonwiller in measuring the specific inductive capacity of a specimen of glass, and fully described by them,* the only change being the substitution for the central swinging brass plate of an aluminium plate of similar dimensions, the lower surface being scraped truly plane; this enables the value of the electrostatic pull to be determined with slightly increased accuracy.

The results are given in Table II, where the overload represents the mass in grammes whose weight counterbalances the electrostatic pull.

Table II.—Results of Absolute Electrometer Method.

Date.	Potential difference.	Distance between plates.	Thickness of selenion.	Overload.		Temp. ° C.	K.
				Without selenion.	With selenion.		
	volts.	cm.	cm.	gramme.	gramme.		
August 11, 1904	4420	2·168	0·880	0·104	0·240	12·5	6·20
" "	4470	2·168	0·880	0·107	0·245	12·5	6·07
May 26, 1905......	2820	1·507	0·858	0·102	0·371	19·3	6·09
May 29, 1905......	5000	1·505	0·858	0·296	1·085	19·8	6·17

Mean value of K...... 6·13 at 16°·0 C.

Measurement of the Specific Inductive Capacity with High Frequency Alternating Electric Forces.

The method used was that employed by one of us in observing the variation in the dielectric constant of water at low temperatures.† The arrangement of the apparatus is shown in fig. 1. Electrical oscillations were

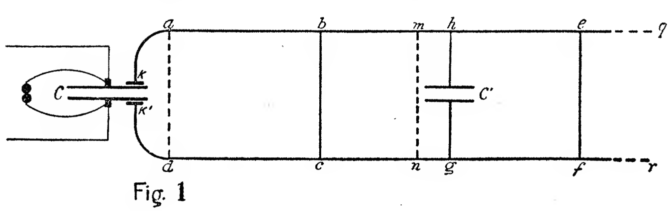

Fig. 1

set up in the two wire circuits *kbck'* (the primary) and *befc* (the secondary) by the oscillatory discharge of the condenser C; Rutherford solenoidal magnetic detectors being placed in the two circuits, and the primary arranged

* 'Phil. Mag.,' June, 1902.

† Vonwiller, 'Phil. Mag.,' June, 1904.

to be in tune with the condenser vibration. The dimensions of the secondary circuit and the capacity of the condenser C′ were chosen as described in the former paper, so that the maximum variation in the demagnetisation of the Rutherford detector in the secondary, was obtained for a given percentage change in the capacity of the condenser C′. This condenser consisted of two parallel circular brass plates 10·4 cm. in diameter and 0·237 cm. thick whose distance apart could be altered. The lengths *bh*, *he*, were each made 200 cm. (altered to 215 and 205 cm. in the second and third experiments, Table III), and as the plates of C′ were moved apart, deflections produced by the two detectors were observed for each position. In fig. 2 is shown the variation of the secondary deflection (corrected to a

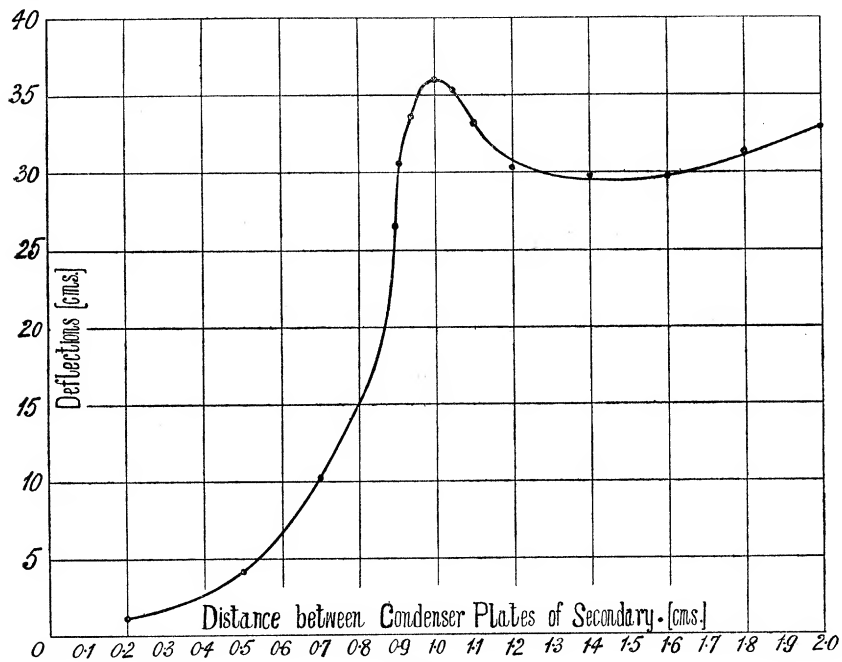

Fig. 2.

standard primary deflection) as the distance between the plates is changed: an inspection of the figure shows that a position of high sensitiveness is obtained when the plates are about 9 mm. apart. The capacity in this position was calculated by Kirchhoff's formula*

$$C = \frac{r^2}{4a} + \frac{r}{4\pi a}\left[-a + a \log \frac{16\pi r\,(a+d)}{a^2} + d \log \frac{a+d}{d}\right],$$

r being the radius of the plates, d their thickness, and a their distance apart.

* 'Abhandl.,' p. 112.

If a plate of a dielectric of radius r_1 less than r and thickness a_1 is placed between the plates of the condenser (the condenser plates touching the dielectric) the capacity, if a_1 is less than $\frac{1}{2}r$, is

$$C = \frac{Kr_1^2}{4a_1} + \frac{r^2 - r_1^2}{4a_1} + \frac{r}{4\pi a_1}\left[-a_1 + a_1 \log \frac{16\pi r(a_1+d)}{a_1^2} + d \log \frac{a_1+d}{d}\right],$$

K being the specific inductive capacity of the dielectric.

A preliminary calculation, assuming K to be the same as at low frequencies, gave dimensions for the selenion plate which would give the same capacity as was obtained when the plates were about 9 mm. apart, with air as the dielectric, and also satisfy the conditions that a should be less than $\frac{1}{2}r$ and that r_1 should be not much less than about $\frac{2}{3}r$, the sensitiveness of the test being decreased as r_1 is decreased, owing to the part of the capacity due to the selenion becoming small in comparison with the whole.

A plate of selenion of suitable dimensions was then prepared in the manner already described and placed between the condenser plates and a number of deflections of both detectors observed, single sparks being used and the mean ratio of the two deflections determined. The selenion was then removed and the plates approached until two positions were obtained, for one of which the ratio of the deflections was slightly above, and for the other slightly below, that obtained with the selenion, the correct position being obtained by interpolation. The results of the observations are given in Table III.

Table III.—Results of Electric Oscillation Method.

Date.	Dielectric between plates.	Deflection of secondary detector.	Distance between plates of C′.	Radius of plate of selenion.	Length, $b-e$, fig. 1.	Temp. °C.	K.
		cm.	cm.	cm.	cm.		
December 15, 1904	Selenion	30·5	2·543	3·190	400	23·0	6·09
,, ,,	Air ……	30·5	0·937	—	400		
January 31, 1905	Selenion	16·4	2·535	3·187	430	24·1	6·16
,, ,,	Air ……	16·4	0·928	—	430		
February 2, 1905	Selenion	23·9	2·535	3·187	410	23·7	6·16
,, ,,	Air ……	23·9	0·9275	—	410		

Mean value of K…… 6·14 at 23°·6 C.

In order to make absolutely certain that when the selenion was between the plates the readings corresponded to those obtained with air between the plates at a distance apart of about 9·3 mm., and not 11 or 20 mm., where the deflections would have the same value (see fig. 2), readings were taken with

one of the condenser plates not touching the selenion, but with a small thickness of glass or mica between, the capacity being thus reduced.

It was found then that the deflections were increased, indicating a nearer approach to resonance, as was to be expected, and the rate of increase was such as to indicate that the position corresponded to that with air between the plates at a distance apart of about 9 mm. rather than 20 mm., where the deflections would also increase with a decrease of capacity.

The frequency of the electric oscillations set up in the system was determined with sufficient accuracy from the dimensions of the secondary circuit when in tune with the primary. W. B. Morton* gives, then,

$$\cot \frac{2\pi x}{\lambda} + \cot \frac{2\pi y}{\lambda} = \frac{2\pi}{\lambda} \frac{C}{s},$$

where x is the distance from the centre of the bridge *bc* to C′, y that from the centre of *ef* to C′, C the capacity of C′ when the two circuits are in tune, s the capacity per unit length of the parallel wires, and λ the wave-length of the electric oscillations (see fig. 1). From fig. 2 it is seen that the position of maximum resonance occurs when the plates are 1 cm. apart, C being then 8·9, as s is equal to $(4 \log d/r)^{-1}$, d being the distance between the wires (30 cm.) and r the radius of the wire (0·021 cm.), $s = 1/29{\cdot}1$; $x = y = 200$ cm., hence λ is found to be 1260 and the frequency about 24,000,000.

Measurement of the Resistance of the Selenion Plate.

Considerable difficulty has been experienced in determining the resistance of the selenion plate. For the measurement of the resistance to have direct connection with the measurements of the specific inductive capacity, it was essential to employ one of the plates actually used in the experiments to determine the latter constant, and this prevented the selenion being cast into a plate of more suitable form for the resistance measurements. After some trials, it was found that good contact with the surfaces of the selenion plate could be obtained by coating them with gold leaf and lightly pressing brass plates against the gilt surfaces. A direct deflection method with a sensitive galvanometer and a voltage of 900 gave no current that could be detected, indicating a specific resistance greater than 10^{14} ohms at 13°·7 C.; finally the method shown diagrammatically in fig. 3 was adopted. Here R represents the selenion plate whose resistance is being measured, and r a resistance of about 1000 megohms (determined accurately by a direct deflection method), consisting of a capillary **U** tube containing alcohol, with platinum wires sealed in at the ends making contact with the liquid. These resistances were

* 'Phil. Mag.,' May, 1897.

connected to one pair of quadrants of a Dolezalek electrometer, the other pair being earthed; the other terminal of R was joined to the positive pole of a battery of accumulators of which the negative pole was earthed, while the other terminal of r was connected as shown to a potentiometer, the ends of

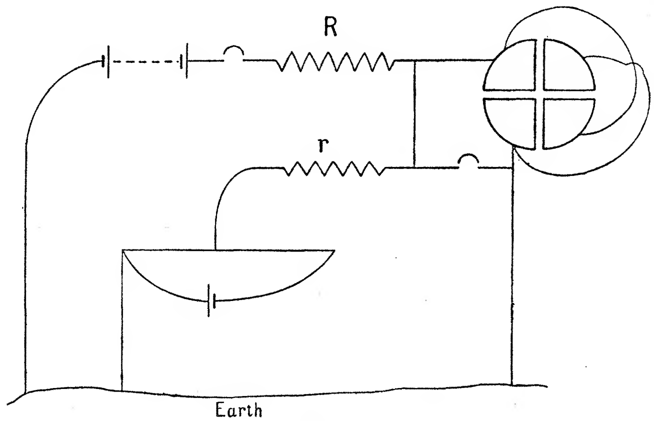

FIG. 3.

which were joined to the poles of a single accumulator, the positive being earthed. The E.M.F. between earth and the end of r, joined to the potentiometer, was varied until the potentials of both pairs of quadrants were the same; if this E.M.F. is e and that of the battery joined to the selenion is E, $e/\mathrm{E} = r/\mathrm{R}$.

Instead of altering e, the end of r joined to the potentiometer was sometimes earthed and the difference of potential between the quadrants determined by observing the steady deflection of the needle (the instrument having been previously calibrated by means of the potentiometer); if this difference of potential is e, we have $e/\mathrm{E} = r/\mathrm{R}$, e being extremely small compared with E.

By this method the resistance of a plate 14·636 cm. in diameter and 0·858 cm. thick, was found to be 11×10^{13} ohms at 20° C. and $3{\cdot}3 \times 10^{13}$ ohms at 25° C., the values of the specific resistance at these temperatures being, therefore, $2{\cdot}2 \times 10^{16}$ ohms and $6{\cdot}5 \times 10^{15}$ ohms respectively.

The value of E in different trials varied from 250 to 600 volts; e varied from 3×10^{-3} to 9×10^{-3} volt; as the maximum sensitiveness obtained was a deflection of 1 mm. for 4×10^{-4} volt, a very high degree of accuracy could not be obtained with a plate of the above dimensions.

The measurements described in this paper were made in the Physical Laboratory of the University of Sydney.